

This listing of claims will replace all versions of claims in the "Substitute Specification" marked version :

Listing of Claims:

1. (Currently Amended) A method ~~Method~~ for teaching a knowledge-based database for automatic defect classification, ~~characterized by the following steps which comprises:~~

(a) selecting ~~Selection of~~ a review data file;

(b) inputting ~~Input of~~ parameters and data by the a user on one page (50) of the a learning mode wherein ~~whereby~~ the parameters and the data are known to the user; [[,]]

(c) starting ~~Starting~~ an alignment procedure and a procedure for adjusting ~~the~~ light intensity;

(d) automatically adjusting ~~Automatic adjustment of~~ the optimal intensity of the lighting by approaching a few defects and if necessary regulating ~~to~~ the optimal illumination;

(e) checking ~~Checking the a~~ detection using a few examples, whereby the optimization of the detection parameters is carried out using pictures; [[,]]

(f) automatically approaching ~~Automatic approach of~~ all defects of the a wafer or ~~the~~ wafers, whereby the respective defect is detected and a descriptor is assigned to the respective defect; [[,]] and,

(g) analyzing and automatically ~~Analysis and automatic~~ grouping of the descriptors of the defect.

2. (Currently Amended) The method ~~Method~~ according to Claim 1, ~~characterized in that~~ wherein the input of parameters and data[[,]] further comprise the selection of ~~the~~ elements present on the a semiconductor substrate, ~~whereby~~ wherein the elements can be memory circuits, logic circuits, a ~~bare~~ blank wafer[[,]] without resist or with resist.

3. (Currently Amended) The method ~~Method~~ according to Claim 2, ~~characterized in that~~ wherein the parameters or data of ~~the~~ layers on the wafer comprise the data of a polymer layer, an oxide layer, a contact or a metal layer.

4. (Currently Amended) The method ~~Method~~ according to Claim 1, ~~characterized in that~~ wherein the user selects ~~the~~ a lighting type, at least one lens ~~used~~ and a focus type.

5. (Currently Amended) The method ~~Method~~ according to Claim 4, ~~characterized in that~~ wherein ~~for the lighting type,~~ bright field, UV or DUV is selected~~[[.]]~~ as the lighting type.

6. (Currently Amended) The method ~~Method~~ according to Claim 4, ~~characterized in that~~ the wherein a default setting is bright field and the lens has a 100X magnification.

7. (Currently Amended) The method ~~Method~~ according to Claim 4, ~~characterized in that~~ wherein a manual two-point alignment is carried out~~[[, whereby]]~~; wherein a first point is aligned manually by approaching a table~~[[, that]]~~; wherein during the teaching of the first point, data ~~are~~ is automatically stored for the auto alignment file~~[[, and that]]~~; and each alignment point is taught with three different magnifications of the lens.

8. (Currently Amended) The method ~~Method~~ according to Claim 1, ~~characterized in that~~ wherein the adjusting of the optimal intensity of ~~lighting~~ illumination is achieved by random selection of a specific number of defects~~[[,]]~~ ; approaching the selected defects~~[[,]]~~ ; taking a picture of each defect; ~~with~~ whereby a start value for the brightness of the illumination and adjustment of the illumination is achieved using a histogram evaluation.

9. (Currently Amended) The method ~~Method~~ according to Claim 8, ~~characterized in that~~ for wherein defects that are no larger than 25 % of a video image width and height are used to adjust the optimal intensity of the illumination. ~~the adjusting of the optimal intensity of the lighting, only defects are used that are no larger than 25% of the video picture width and height.~~

10. (Currently Amended) The method ~~Method~~ according to Claim 8, ~~characterized in that~~ wherein 20 defects are used to adjust the intensity of the ~~lighting~~ illumination.

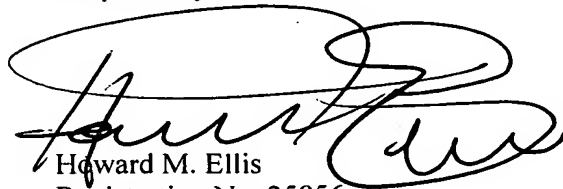
11. (Currently Amended) The method ~~Method~~ according to Claim 1, ~~characterized in that~~ of wherein the defects on the wafer that are automatically approached ~~defects on the wafer,~~ have pictures ~~are~~ taken and which are temporarily stored until pictures are taken of all the defects.

12. (Currently Amended) The method ~~Method~~ according to Claim 11, ~~characterized in that~~ wherein after all the pictures are taken, ~~these~~ they are shown on ~~the a~~ display ~~(11)~~ as thumbnails.

13. (Currently Amended) The method ~~Method~~ according to Claim 12, ~~characterized in that~~ wherein a few thumbnails are rejected if the thumbnails exceed a threshold value for the focus.

14. (Currently Amended) The method ~~Method~~ according to Claim 1, ~~characterized in that~~ wherein the analysis and automatic grouping of the descriptors of the defects divides the thumbnails of the defects recorded into groups, and ~~that~~ on the display the first nine examples of a selected group of defects are displayed in a thumbnail representation.

Respectfully submitted,



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Applicant(s): Dirk SOENKSEN, et al.

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AUTOMATIC DEFECT CLASSIFICATION

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SUBSTITUTE SPECIFICATION – MARKED VERSION
37 CFR 1.125 (b and c)

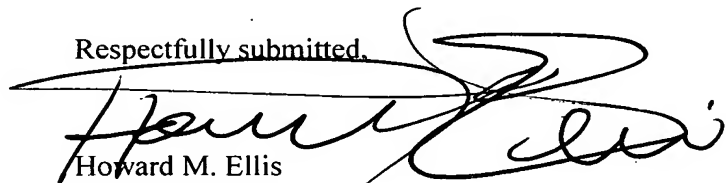
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Alexandria, VA 22313-1450

Sir:

This is to certify the attached "Substitute Specification", Marked Version is in compliance with the requirements under 37 CFR 1.125(b and c) and contains no new matter.

The Abstract at the back of the attached Substitute Specification corresponds substantially to the Abstract appearing in the above International Application.

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**METHOD FOR TEACHING A KNOWLEDGE-BASED DATABASE FOR
AUTOMATIC DEFECT CLASSIFICATION**

Cross Reference to Related Application

[0001] This application claims the benefit of International Application
5 PCT/EP2004/051008, filed June 3, 2004, which claims priority from German Application 103
31 646.9, filed July 12, 2003.

Background of the Invention

[0002] The invention relates to a method for teaching a knowledge-based database for
automatic defect classification.

10 [0003] In semiconductor manufacturing, wafers or masks are processed sequentially
in a number of process steps during the manufacturing process. With increasing integration
density, the demands of the quality of the structures formed on the wafers increase. In order
to check the quality of the structures formed and to be able to find possible defects, the
demand for quality, precision, and reproducibility of the components and process steps used
15 with the wafer is critical. This means that during production of a wafer with a number of
process steps, a reliable and early recognition of defects is especially important. In this
process, it is necessary to classify the defects that occur in order to thus achieve a fast
processing and testing of the wafers.

[0004] In earlier versions of ~~the automatic defect classification~~ "Automatic Defect
20 Classification" (ADC), it was necessary to proceed with a manual classification of the defects
on a wafer or on a mask. The teaching of a knowledge base was thus extremely time
consuming.

Summary of the Invention

[0005] The object of this invention is based on the task of producing to provide a
25 method with which a simple and fast possibility is offered for creating all the data and files
(knowledge base, auto alignment, focus setup) necessary for the an "ADC run."

[0006] This object is achieved by a ~~method with the characteristics of Claim 1~~ method
of learning a knowledge-based database for automatic defect classification wherein a review
data file is selected, and parameters and data are input by a user on one page of a learning
30 mode, where the parameters and the data are known to the user. Additionally, an alignment

procedure and a procedure for adjusting light intensity are used. Optimal light intensity is automatically adjusted by approaching a few defects and if necessary regulating the optimal illumination. Detection is checked using a few examples, wherein the optimization of the detection parameters is carried out using pictures. Respective defects are detected and a
5 descriptor is assigned to the respective defect by automatically approaching all defects of a wafer or wafers. Descriptors of the defect are then analyzed and automatically grouped.

[0007] It is especially advantageous that Leica ADC HP offers a simple and fast option for creating data and files (knowledge base, auto alignment, focus setup) for an ADC run. To do this, in part specified data and files are used. Since a manual classification of the
10 defects on a wafer is no longer necessary, as in earlier ADC versions, the time needed to create a new ADC protocol for teaching a knowledge base can be reduced by up to 50%. Additionally, in many cases the quality of the knowledge base improves because of the "pregrouping function" that is included, which in turn has a direct influence on the precision of the ADC run. ADC HP is described as an independent "learn mode" ~~in the Leica ADC~~. In
15 individual steps, the user must specify, confirm and if necessary change the required data. The individual steps are shown as separate pages in the Leica ADC HP dialog. The user prompts for the individual ~~page~~ pages are in the so-called wizard style, i.e., using <Back> and <Next> buttons. In contrast to the previous learning mode, the new learning mode has the advantage that it is uncomplicated and requires a reduced number of steps that have to be
20 carried out by the user in the proper sequence. ~~For~~ In the previous learning mode, preclassified defects were required. All the new learning mode needs is one or more wafers with as many unclassified defects as possible.

[0008] Since during a few of the steps an interaction with the Viscon interface is necessary, the Leica ADC HP dialog is not displayed modally, but top-most. The dialog can
25 automatically be hidden or the user can make it hidden or visible again.

~~The method for teaching a knowledge-based database for automatic defect classification comprises the following steps:~~

~~— Selection of a review data file~~

~~— Input of parameters and data by the user on one page (50) of the learning mode,~~

~~whereby the parameters and the data are known to the user,~~

- ~~— Starting an alignment procedure and a procedure for adjusting the light intensity;~~
- ~~— Automatic adjustment of the optimal intensity of the illumination by approaching a few defects and, if necessary, regulation to the optimal illumination;~~
- ~~— Checking the detection using a few examples, whereby the optimization of the detection parameters is carried out using pictures;~~
- ~~— Automatic approach of all defects of the wafer or the wafers, whereby the respective defect is detected and a descriptor is assigned to the respective defect, and~~
- ~~— Analysis and automatic grouping of the descriptors of the defects.~~

[0009] The input of parameters and data includes the selection of the elements present on the semiconductor substrate, whereby it is possible for memory circuits, logic circuits, and a blank wafer without resist or with resist to exist as elements. The parameters or data of the layers on the wafer include the data of a polymer layer, of an oxide layer, of a contact or of a metal layer.

[0010] The user selects the illumination type, at least one lens used and a focus type. For the illumination type, bright field, UV or DUV can be selected. The default setting is bright field, and the default for the lens is 100X magnification.

[0011] A manual two-point alignment is carried out, whereby a first point is aligned manually by approaching a table. During the learning of the first point, data are is automatically stored for the auto alignment file. Each alignment point is learned with three different magnifications of the lens. The adjustment of the optimal intensity of illumination is carried out by random selection of a specific number of defects. Then A subsequent approach of the selected defects are approached and taking a picture is taken of each defect. [[,]] whereby a A starting value for the brightness of illumination and the adjustment of the illumination is achieved using a histogram evaluation of the pictures. Defects that are no larger than 25% of the video image width and height are used to adjust the optimal intensity of the illumination. For adjusting the optimal intensity of illumination, only defects are used that are no larger than 25% of the video image width and height.

[0012] Twenty defects will be used to adjust the intensity of illumination. Of the defects on the wafer that are approached, pictures are taken and stored temporarily until pictures are taken of all defects. After all the pictures have been taken, they are shown on the display as thumbnails. A few thumbnails are rejected if the thumbnails exceed a threshold value for the focus. The analysis and automatic grouping of the descriptors of the defects divides the thumbnails of the defects that have been produced ~~of the defects~~ into groups. On the display, the first nine examples of a selected group of defects in a thumbnail representation are shown.

Brief Description of the Drawings

[0013] In the following, the invention will be explained in more detail using embodiment examples that are shown schematically in the figures. The same reference numbers in the individual figures refer to the same elements. The following are shown in detail:

Fig. 1 shows a schematic structure of a wafer inspection device as an overview in which the method according to the invention is implemented;

Fig. 2 shows the ADC HP toolbar button with which the user calls the function for automatic defect recognition;

Fig. 3 shows the ADC HP call of the "ADC" menu;

Fig. 4 shows a "Leica ADC HP Control Desk" window that clearly summarizes, in one window, the ADC tasks that are already partially available in earlier ADC versions;

Fig. 5 shows a page of a learning mode that the user calls up and in this process an input file opens, i.e., specifies a review data file;

Fig. 6 shows a page of the learning mode that the user calls and thus assigns a name for a "recipe file";

Fig. 7 shows a page of the learning mode by which the user specifies the ADC knowledge base data;

Fig. 8 shows a page of the learning mode by which the user carries out the teaching and an automatic alignment;

Fig. 9 shows a page of the learning mode by which the user carries out an automatic light adjustment;

5 Fig. 10 shows a page of the learning mode by which the user achieves an optimization of the adjustment of the detection ~~parameter~~ parameters;

Fig. 11 shows a representation of the thumbnails on the screen;

Fig. 12 shows a representation of a message box;

Fig. 13 shows a representation of a change sensitivity dialog;

10 Fig. 14 shows a representation of a window that gives the user a warning message;

Fig. 15 shows a representation of an information window for acceptance of the new detection threshold;

15 Fig. 16 shows a page of the learning mode by which the user carries out an automatic generation of a knowledge base;

Fig. 17 shows a representation of the "defect code mapping" dialog;

Fig. 18 shows a representation of an information dialog;

Fig. 19 shows a representation of a dialog for starting the "ADC run";

Fig. 20 shows a representation of a finish dialog;

20 Fig. 21 shows a representation of a report dialog; and

Fig. 22 shows a representation of the printed Easy ADC Report.

Description of the Preferred Embodiments

[0014] Fig. 1 shows a schematic structure of a wafer inspection device 1 as an overview, in which the method according to the invention is implemented. On a base frame 2, a-scanning table 4 is integrated as a placement table for the wafer 8. ~~The scanning~~ Scanning

25

table 4 can be driven in an X-coordinate direction and a Y-coordinate direction. ~~The wafer~~
Wafer 8 to be tested is placed or hooked on the scanning table 4. An observation device that
is preferably equipped with a microscope lens 7 is connected to the base frame 2 by way of a
carrier unit 9. ~~The microscope~~ Microscope lens 7 makes possible the enlarged observation of
5 wafer 8. Several microscope lenses 7 can be provided on a revolving unit (not shown) so that
observation with different enlargements is possible. The structures of the wafer 8 that are
observed when they are enlarged can be observed directly using an eyepiece 5 or by way of a
display 11 that is connected to a CCD camera 13. Additionally, an electronic unit 15 is
provided with which a system automation can be achieved. In particular, the electronic unit
10 15 is used to control the scanning table 14, for reading out the camera 13 and for controlling
the display 11. ~~The wafer~~ Wafer holder 16 is usually designed in such a way that it can hold
the wafer 8 to be tested so that it is fixed during the testing period. ~~The scanning~~ Scanning
table 14 is designed so that it can be driven in each perpendicular X-coordinate direction and
one Y-coordinate direction. In this way, each point to be observed on the wafer 8 can be
15 brought under the optical axis 7a of the microscope lens 7 (Fig. 1).

[0015] Fig. 2[[.]] shows the ADC HP toolbar button 20, with which the user calls the
function for automatic defect recognition. The ADC HP dialog is called using an ADC HP
toolbar button 20 or using a main toolbar 19 of the Viscon application 21 in "ADC" menu or
20 in the context menu of the "ADC" dialog (see Fig. 3). Every user (starting from the
"operator" user level) has access to this menu entry. Since ADC HP is a separate option, the
menu entry is only visible if ADC HP is also installed. This option is protected, as before,
using a registry entry that is generated by the installation program when this option is
selected. If a program is already loaded in Viscon, the menu entry will be shown deactivated.

25 [0017] Fig. 4 shows the "Leica ADC HP Control Desk" window 25. It combines the
ADC tasks, some of which were already available in earlier ADC versions, clearly in a
window and is used as the starting basis to start individual modules 26, 27, 28, and 29. In
detail, this includes:

[0018] “Learn recipe”: learning and creation of a new ADC recipe and a knowledge base with subsequent ADC run (run recipe), “Edit recipe”: for processing an available knowledge base, “Expand recipe”: for expanding an available knowledge base and “Run recipe”: to start an ADC run.

5 **[0019]** One button is provided for each of the individual modules. In the current embodiment, this includes a “learn recipe” – button 26, an “edit recipe” – button 27, an “expand recipe” – button 28 and “run recipe” – button 29. When the individual buttons 26, 27, 28, 29 are actuated, the individual tasks are executed. Those tasks that were already present in the earlier ADC version will only be discussed briefly here.

10 **[0020]** “Edit recipe”: After pressing this button 27, the user has to select an available knowledge base file. This is started by the external application “KB Wizard” and the contents of the file are displayed. The data can be processed there and the knowledge base as a whole can be tested.

15 **[0021]** “Expand recipe”: With this button 28, the user selects an available knowledge base file and a review data file. During the subsequent ADC run, new data are collected and temporarily stored in the background. Once the run is completed, the temporary data and the knowledge base (KB) file used will be loaded by the “KB Wizard” application and displayed. The user can now take the new data selectively over into the knowledge base.

20 **[0022]** “Run recipe”: By the selection of button 29, a review data file and an ADC recipe will be selected and an ADC run will be started. All defects selected by the user will be detected automatically and classified using the knowledge base file noted in the ADC recipe. The results will be written again at the end as a review data file.

25 **[0023]** The task connected with the actuation of the “learn recipe” – button 26 will be described in detail in the following.

[0024] The ADC HP learning mode is displayed as a non-modal dialog. The user must input the necessary data and/or select files in eight successive steps, i.e. on eight pages. The last page only represents the result of the ADC HP learning process.

[0025] To do this, the user can use ~~the~~ <Back> and <Next> buttons 30, 31 (wizard style), as long as the current status allows it, to go to the previous or to the next step (see Fig. 5).

[0026] In general, it is true that the display of the individual pages is not user-level-dependent. The exceptions are additional user interface elements that are only visible to the development user level. These are now visible during the development phase and will be removed in the release version and be generally invisible for all user levels.

[0027] Fig. 5 shows ~~one~~ page 33 of the learning mode that the user calls up and thereby opens an input file 34, i.e., specifies a review data file. Page 33 is designated with "open input file." On page 33, the data file is displayed (without path). Using a file open [[-]] button 35, the directories are displayed for the user for data input. If an input file has been determined, it is temporarily opened, but the Viscon sequencer is not started. The file "EasyADCLearn.vsl" is used as the script file, hard coded. The necessary data for LotId (lot identification), WaferId (wafer identification), StepId (step identification) and SetupId (setup identification) of the first wafer are read out from the open file. Then the file is closed again. Any standard settings (e.g. Auto Start) are not affected by the process and/or will be put back to the original status. The user can cancel the procedure with a cancel button 39.

[0028] Fig. 6 shows ~~another~~ page 38 of the learning mode that the user calls up and thereby assigns a name for a recipe file. Page 33 is designated with "recipe file." Actuating ~~the~~ back button 30 is not allowed in ~~this~~ page 38. Actuation of ~~the~~ next button 31 is allowed if a valid input file 37 has been selected. The user can cancel the ADC HP learn mode with ~~the~~ cancel button 39. The Leica ADC HP recipe file is displayed in an edit box 40. The previously read name components are summarized according to specification, and the resulting file name (with the extension ".vsl") is displayed. The name components are separated by a "_" symbol (underscore).

[0029] Invalid letters in the resulting file name will be removed and hyphens will be replaced with underscores. The user also has the option of changing the specified name (completely or partially) as desired. The file "EasyADCRun.vsl" is used as a template for the ~~result~~ resulting recipe file (sequence control file during an ADC run) (hard coded). Page 38

contains several checkboxes 41, 42, 43 and 44. ~~The checkboxes~~ Checkboxes 41, 42, 43 and 44 are used to determine the name components. In this case, LotID, StepID and SetupId are used as defaults. The resulting file name (without the extension ".vsl") is also used as a default for other files (auto alignment, focus setup file, etc.). The data file of the results
5 "result data file" is always written with the same name as the input file and the same format type and in the standard result directory. ~~The back~~ Back button 30 is permitted and ~~the next~~ button 31 is permitted if at least one name component has been selected. ~~The cancel~~ Cancel button 39 is permitted.

[0030] Fig. 7 is a shows page 50 of the learning mode by which the user specifies data
10 for the ADC knowledge base. ~~This page~~ Page 50 is designated as "ADC basic data." In a selection column 51 with the designation "structure type," the user can choose between "memory" and "logic." An additional selection or a blank, unstructured wafer "bare wafer" is also possible. To determine the ADC run mode (repetitive or random mode) and/or auto alignment modes (normal auto alignment or bare wafer alignment), the procedure is
15 according to the selection. The default setting is set to "logic."

[0031] In ~~another~~ selection column 52, ~~with the~~ which has designation layer type, the user can select whether one or more layers will be applied to the wafer. Also of interest is which layers will be applied to the wafer. Without resist is "w/o resist," with resist is "with resist" (see Fig. 7). The resists, or also other layers, are applied on wafer 8 or the
20 semiconductor substrate. The default setting is "w/o resist."

[0032] In other setting options, the user can select the layer type. A polymer layer is designated with "poly," an oxide layer with "oxide," a contact with "contact" or a metal layer with "metal." The sequence of application of the different layers can also be selected. For example, an oxide layer (oxide) is applied before the polymer layer, this is designated with
25 "before poly." The selection of the layer type metal allows the user the choice between a single metal layer (metal 1), a double metal layer (metal 2) and an n-fold metal layer (n-metal). ~~Whether~~ The determination of whether a main layer or a subordinate layer is involved, is used to determine the random mode and the focus type. The default settings for the layers are "poly," for "oxide": before poly and for "metal": metal 1. Oxide and metal sub-

layer radio boxes are only activated if "oxide" or "metal" has previously been selected. Otherwise they are shown deactivated. In ~~another~~ selection column 53, the user can select the "illumination mode." The radio boxes with the designation BF for bright field, UV for ultraviolet and DUV for deep UV are available to the user. In a list box 54, the lenses that are
5 available are displayed to the user, whereby only the lenses that fit the selected ADC type are displayed. The default setting is bright field "BF," and a lens with 100X or lower magnification is suggested.

[0033] The following table (Table 1) shows the resulting focus setting using the selected data:

Layer/ADC type	Focus type	Offset value for TV focus
Poly	TV focus	400
Poly resist	TV focus	0
Oxide before poly	Laser	-
Oxide before poly resist	TV focus	0
Oxide after poly	TV focus	2000
Oxide after poly resist	TV focus	2000
Contact	Laser	-
Contact resist	Laser	-
Metal 1	TV focus	1500
Metal 1 resist	TV focus	0
Metal 2	TV focus	1800
Metal 2 resist	TV focus	0
n-Metal	TV focus	2500
n-Metal resist	TV focus	0

[0034] For TV focus, the default values of the “TV Focus Flexible 2” mode are used. ~~The back~~ Back button 30, ~~the~~ next button 31 and ~~the~~ cancel button 39 are permitted in this window. If ~~the~~ next button 31 is pressed, the ADC HP dialog becomes invisible.

5 [0035] A copy of the “EasyADCLearn” files is created and specific actions are adapted (auto alignment) and data (grab setup).

[0036] The same changes are made for the named copy of the “EasyADCRun” file (the later ADC run recipe). The input file is loaded with the adapted script file, and the Viscon NT sequencer is started. The file is automatically processed up to wafer selection. The
10 standard wafer selection dialog is used and displayed.

[0037] As a default, all available wafers are selected (default setting in easy ADC script file).

[0038] Fig. 8 is a page 60 of the learning mode, by which the user carries out the teaching and an automatic, or at least semi-automatic, alignment, ~~this page 80~~ 60 is
15 designated as “alignment procedure.” After actuation of the wafer selection by the user, the first wafer is loaded and the file is processed up to auto alignment. Depending on the setting of the layers present on the wafer, the learning mode of the corresponding auto alignment will be started (semi- auto or later bare wafer alignment). The user can carry out a manual two-

point alignment whereby only the very first point is aligned manually (driving of the table using joystick or by mouse double click in the live video image) and confirmed. During the teaching of the first point, data ~~are~~ is automatically stored for the auto alignment file. Each alignment point is taught with three different lens magnifications, whereby the highest
5 magnification lens is specified by the selection on page 50 (ADC basic data).

[0039] The second point is already taught and aligned automatically using the stored data of the first point. The selected ADC lens is always specified by the software. This lens must be used since it will be needed for the later light adjustment (method used: alignment point).

10 [0040] If the learned structure of the first input point is not found on the second alignment point, the second point will be "offset" toward the center point of the wafer and the structure will be searched ~~for there~~ again. The second point is "offset" by a maximum of six dies before the alignment aborts with an a defect. In this case, an information window will be displayed to the user that says that the alignment has been aborted and the wafer is
15 discharged.

[0041] After the end of the alignment, the Viscon sequencer is paused (incorporated pause action (without message box display) in the easy ADC script file), the ADC HP dialog becomes visible again and displays the next page. ~~The next~~ Next button 31 is not permitted if alignment is carried out and/or has been aborted due to an a defect. ~~The next~~ Next button 31
20 is permitted if the alignment was successful. ~~The cancel~~ Cancel button 39 is permitted and cancels the entire ADC HP learning mode.

[0042] Fig. 9 is a page 70 of the learning mode by which the user carries out an automatic light adjustment. This page is designated as "light adjustment." After pressing a "perform automatic light adjustment" button 71, a specific number of points (defects from the
25 data file) will be selected randomly. If size information is available, only defects will be selected that are greater than 25% of the video image width and height. These defects are approached and pictures are taken. A "lamp brightness" start value is determined using a histogram evaluation and adjusted at the microscope. This means that the brightness will be

regulated down so that no defect image is "overwritten." To do this, all available color channels will be tested and adjusted in an appropriate way.

[0043] Then an automatic light adjustment is carried out. If it is successful, the data obtained will be stored in the knowledge base file. As a default, 20 points (defects) are used for the "starting value" determination and the "alignment" method of the light adjustment is used.

[0044] Page 70 ~~shows a~~ contains Statusbox 72 ("progress control box") and an Infobox 73 "read only edit box." During the automatic light adjustment, the progress is displayed in Statusbox 72. A status text is displayed in ~~the~~ Infobox 73 whether this is successful or unsuccessful. ~~The back~~ Back button 30 is not permitted when the light adjustment is being carried out. ~~The back~~ Back button 30 is permitted if the light adjustment is rejected. The wafer is discharged, and page 50 "ADC basic data" is displayed. ~~The next~~ Next button 31 is permitted if the light adjustment was successful. The cancel button is permitted if light adjustment has been carried out and in this process all open files were closed and deleted.

[0045] Fig. 10 is a page 80 of the learning mode, by which the user achieves an optimization of the setting of the detection parameters. ~~This page~~ Page 80 is designated as "optimize ADC detection." The process is started using a button 81, which is designated as "start optimization." The optimization function will ensure that the standard values for focus adjustment and detection parameters function on the selected wafer. If this is not the case, the user has the option here again of changing the specified standard values. After button 81 is pressed, the Viscon sequencer is started, defects are selected, approached and pictures are taken. The text on button 81 then changes into "stop optimization." The progress of the picture taking is displayed in a status box 82. The user can then cancel the procedure by pressing it again. If all the necessary pictures have been taken, they will be displayed in another dialog in an additional representation on the screen as thumbnails. Ten defects (hard coded) are used for optimization. The number can be changed using a registry entry and/or development user level. ~~The back~~ Back button 30 is not permitted if the detection optimization is being carried out. ~~The next~~ Next button 31 is not permitted if the detection

optimization is carried out. ~~The cancel~~ Cancel button 39 is not permitted if the detection optimization is carried out.

[0046] By pressing ~~the~~ <Start Optimization> button 81, the Viscon sequencer is started again, the button text changes to "stop optimization" and a specified number of defects of the current wafer is selected.

[0047] The defects are approached and in this process a special ADC action is initiated. This action takes the pictures, detects the defects using an ADC routine that is already developed and stores the pictures temporarily until pictures of all the defects have been taken. The progress of this procedure is displayed by means of the status box. During picture taking, the user can cancel the procedure by repeatedly pressing the button.

[0048] Fig. 11 shows a representation of several thumbnails $91_1, 91_2, 91_3, \dots, 91_n$ on display 11. If all pictures have been taken, the ADC HP dialog is switched to invisible and the pictures are displayed in a thumbnail dialog 90 (complete picture display on the screen). The Viscon sequencer pauses at this time.

[0049] ~~The thumbnail~~ Thumbnail dialog 90 is basically divided into a first area 91, a second area 92, a third area 93 and a fourth area 94. ~~The first~~ First area 91 comprises a horizontal list in which ~~the~~ thumbnails $91_1, 91_2, 91_3, \dots, 91_n$ are represented with detection marking and defect ID (defect identification). The currently selected picture is shown in the second area 92 with a maximum resolution of 640x480 pixels. If available, the reference pictures are also shown, reduced, in the third area 93. The current picture selection can be changed using a mouse click, cursor keys and/or ~~the~~ browse buttons 95 under the defect picture.

[0050] The defect marking can be switched off and back on again using a <Hide Defect Detection> button 96. ~~The browse~~ Browse buttons 95 are used for selection and display of the next or the previous defect picture. ~~The~~ <Hide Defect Detection> button 96 is designed as a toggle button, and in this way the detection marking can be made visible or invisible.

[0051] ~~A focus~~ Focus difference – defect/reference button 97 makes it possible to display a message box 86 (see Fig. 12). During operation, the selected defect picture (and available reference pictures) will be thrown away, i.e., deleted from the display. If an internal

threshold value (default: 30%) of the unsatisfactory pictures thrown away (bad focus pictures) is exceeded, the focus values are changed (i.e., change from laser to TV focus or change of the TV focus offset in 500 nm steps). The defects are then approached again and data recorded. To do this, the thumbnail dialog 90 is closed and the ADC HP dialog will be displayed again during the scan procedure.

[0052] ~~A-wrong~~ Wrong defect detection button 86 makes it possible for the detection threshold for the selected picture to be determined again. To do this, a new dialog 80 is displayed (see Fig. 10).

[0053] ~~A-refresh~~ Refresh button 87 makes it possible for the average value of the threshold of all pictures in the list to be determined, and all detections will be recalculated with this new average value. The list will then be set up again. Pictures with "autothreshold" (-1) are not used to determine the average value.

[0054] ~~A-default~~ Default button 88 makes it possible for all the changes in the detection parameters of all pictures to be reversed. The list is set up again with the original values.

[0055] The dialog is closed with an apply button 89, the average value of the threshold is calculated and taken over as a global detection parameter. Pictures with "autothreshold" (-1) are not included for determining the average value. The optimized dialog is closed, the ADC HP dialog is switched so that it is visible again and the new overall detection threshold is entered in the knowledge base.

[0056] ~~The-cancel~~ Cancel button 39 closes the optimize dialog, and the ADC HP dialog becomes visible again. All changes are rejected.

[0057] Fig. 13 is an illustration of a dialog 100 for "change sensitivity." Dialog 100 is used to determine the optimum setting for the detection threshold of the selected defect picture. ~~The-defect~~ Defect picture 101 is displayed centrally with the associated detection threshold in dialog 100. If indirect automatic detection threshold has been used due to prior adjustments (on page 50 "ADC Basic Data"), a value of 50% is assumed.

[0058] The sensitivity of the detection can be reduced or increased using two buttons 102. ~~The-defect~~ Defect picture 101 shown in the center shows the defect recognition with the currently selected sensitivity. The value is shown under defect picture 101. ~~A-reduced~~

Reduced picture 103 is shown on the left next to defect picture 101 and shows the change in detection with reduced sensitivity. Also, a reduced picture 103 is shown at the right next to defect picture 101 and shows the change of the detection with increased sensitivity. By clicking with the mouse on one of the reduced pictures and/or by pressing on the buttons 102
5 lying under them, the current sensitivity is changed to this value and the picture is now shown in the center. The changes on the left and right will then be recalculated.

[0059] ~~A hide~~ Hide defect detection button 105 is designed as a toggle button. In this way, the detection marking is switched to visible or invisible.

[0060] ~~A slider~~ Slider 106 with the designation "sensitivity step size" is used to
10 change the magnitude of changes of sensitivity during actuation of button 102. ~~A delete~~ Delete image button 107 is used to reject a defect for further evaluation. The defect is removed from the list of the optimization dialog. This dialog is closed, and the user goes to the previous dialog.

[0061] Fig. 14 is a representation of a window 110 that gives the user a warning
15 message. If an internal threshold (default: 30%) of the "wrong detection" pictures rejected is exceeded, new defects can be selected (automatically), approached and data recorded. ~~An~~ apply Apply button 107 starts the application. Fig. 15 is a representation of an information window 110 for acceptance of the new detection threshold. The information window informs the user that by acceptance of the new detection threshold the detection of all the other
20 pictures will also change. The new value will be applied to all other pictures by pressing on the <Refresh> button 87 in the optimize dialog 90.

[0062] By operating the <Yes> button 111, the detection threshold of the center image display is taken over and the user goes back to the previous dialog 100.

[0063] By operating the cancel button 39 change in dialog 100, all changes made are
25 rejected and the user goes back to the previous optimization dialog 90 (see Fig. 11).

[0064] Fig. 16 ~~is one~~ shows page 120 of the learning mode, by which the user carries out an automatic generation of a knowledge base. With a start collecting data button 121, all the necessary data for all defects of all selected wafers are accepted and recorded.

[0065] The status is displayed to the user in a Statusbox 122 and an Infobox 123. The
30 Infobox 123 displays the defects "yet to be processed" from the total number (e.g. "267 of

750"). Operating the back button 30 is not allowed when the data acceptance procedure is running. Operating the next button 31 is also not allowed if the data recording procedure is running. Operation of the cancel button 39 is not allowed when the data recording procedure is running. If the actuation of the cancel button 39 is allowed, all open files will be closed and deleted.

[0066] The sequence is as follows: The Viscon sequencer is started again and all defects of the input file are selected. In a first step, defects on the wafer or wafers are approached, pictures are taken, descriptors generated and stored in the ADC result data on the defect. The pictures of the defects will be stored with the following settings:

- "Write to Archive File"
- "All Images"
- "Image Compression": yes
- "Leica-ImageStore": no

[0067] In a second step, the Viscon sequencer pauses on the basket level (before storing the output file).

[0068] In a third step, the generation of the groups from the collection of descriptors occurs ("pregrouping").

[0070] In a fourth step, the pregrouping attempts to create a maximum of 20 groups. Groups with less than two examples are rejected. The resulting groups are copied temporarily to the knowledge base, whereby the defect code and defect description of each group are "numbered" for the first time (1, 2, 3, etc., or EasyClass1, EasyClass2, EasyClass3, etc.)

[0071] In a fifth step, a dialog 130 is displayed for dividing the defects, i.e., "defect code mapping" (see Fig. 17). The "defect code mapping" "Defect code mapping dialog" 130 is essentially represented by a first window 131, a second window 132, a third window 133 and a fourth window 134. In the first window 131, a binder icon is shown for each group generated in the fourth step. Window 132 displays the pictures of the first nine examples of the selected group in a thumbnail representation. Window 133 displays the actual defect code table. By selection selecting of a defect code and pressing a <Map> button 135, this code is assigned to the selected classes. The icon of this class changes in that it gets a green hook 136 and the corresponding defect code text is displayed. This "mapping" can also be executed by

a double click in the defect code table. When the <Delete Group> button 137 is pressed, the currently displayed group is marked for deletion. The corresponding binder icon gets a red cross 138.

[0072] When pressed, a toggle button 139 designated with "optimize image display" makes it possible for a section around the defect marking in original size of the example pictures to be shown. If the defect marking in an example picture is too large, the display does not change. By pressing ~~on the~~ toggle button 139 on again, you go to the reduced full picture display. Operation of an apply button 129 is allowed if all defect groups have been handled, i.e., mapped or marked for deletion.

10 [0073] In a sixth step, there is an attempt to reduce the number of individual examples per mapped group (groups marked as for deletion will not be used and rejected). This is necessary so that specific groups with a lot of defects do not dominate the knowledge base and defects can preferably be assigned to this class. The result is taken over into the knowledge base, and the user comes to the ADC learning mode during operation of ~~the~~ cancel button 39 on the display 11 of the information dialog 140 shown in Fig 18. After
15 operating ~~the~~ <Yes> button 141, the "mapping" in the entire ADC learning mode will be canceled.

[0074] Fig. 19 shows a representation of a dialog 150 for starting an ADC run. With a start ADC run button 151, after button 151 is pressed there is a classification of all defects of
20 the selected wafers "offline" (i.e., without approaching them again). The classification is carried out with the current ADC knowledge base. Dialog 150 includes a Statusbox 152 and an Infobox 153. The display of the defects yet to be classified of the total number is displayed in Statusbox 153 (e.g., "123 of 750").

[0075] Operation of ~~the~~ back button 30 is not permitted if Offline ADC is running.
25 Operation of ~~the~~ next button 31 is not permitted if Offline ADC is running. Also the operation of ~~the~~ cancel button 39 is not allowed if Offline ADC is running. If the operation of ~~the~~ cancel button 39 is allowed, all open files will be closed and deleted. If ~~the~~ next button 31 was pressed, the sequencer is started again. The result data file is written and the sequencer ends automatically, whereby all files that are still open are closed.

[0076] Fig. 20 shows a representation of a dialog 160 ~~for the end~~ which is the finish screen. An Infobox 161 is provided for an output file. ~~The~~ Infobox 161 is used to display the stored data files. Only the file name is displayed.

[0077] The Easy ADC VSL file is also displayed in a Read Only Editbox 162. The display of the generated "ADC run" file appears in ~~the~~ Infobox 162. Only the file name is displayed. The complete path is displayed in a tool tip.

[0078] The number of "total defects" is displayed in ~~an~~ Infobox 163. The total number of all defects can be read ~~in~~ Infobox 163.

[0079] The "defects detected" will be displayed in ~~an~~ Infobox 164. The "redetection" of the defects in percent will also be displayed in ~~an~~ Infobox 166. The display of the defects detected with ADC is shown absolutely and as a percentage. ~~An~~ LED 149 displays in color whether the percentage lies above the predefined value. If the value lies above the predefined value, LED 149 is green, otherwise LED 149 is red. The number of classified defects is displayed in a Read Infobox 165. The percentage of classified defects "classifiability" is also shown in ~~an~~ Infobox 167. The display of the defects classified with ADC is shown absolutely and as a percentage. ~~An~~ LED 148 shows in color whether the percentage lies over a predefined value. Green means that the percentage lies over the predefined value. If the value lies below that, the display is red.

[0080] By operating a report button 147, a report dialog 170 is displayed (Fig. 21). ~~This report~~ Report dialog 170 is user-dependent. Another report is displayed only starting at the 'engineer' user level. The operation of the finish button 146 ~~is allowed will be ended~~ will end the process. ~~This report dialog 170 is user dependent.~~

[0081] Fig. 21 shows ~~the~~ report dialog 170 with the expanded display of data in ~~an~~ Infobox 171. The following data are output: file information: (P) output file name (+path), recipe information: (P), ADC HP recipe file name (+path), knowledge base file name (+path), auto alignment file name (+path), focus type "LASER" or "VIDEO" with grab setup file names (+path), knowledge base information (A) (P), lens used, contrast method used, focus type, aperture used, light intensity used, statistical information (P), number of wafers, total number of defects, number of classified defects, number of ADC classes, defects per class (in matrix form), number of detected defects, absolute/percent, number of classified defects,

absolute/percent, number of classifications per ADC defect class (P), performance information: (A) (P), accuracy, purity, confusion matrix (A) (P) and a defect list (A). A sorted table contains the following data per data record: the slot number, the event number, the manual classification, the ADC classification, the ADC classification with confidence value and the ADC classification with confidence value. In this case, only the first 300 entries are output. (A) means that these data are visible only in the expanded report. (P) means that the data can be printed out.

[0082] ~~The report~~ Report dialog 170 is provided with a print button 171. A preview of the ADC HP report is displayed on the display 11. The printout can be printed out using a standard printer. The printout is in landscape format since in portrait format the paths are usually not completely displayed or printed out.

[0083] Fig. 22 is a representation of a printed Easy ADC Report 180. When a save button 173 is operated (see Fig. 21), the ADC HP report can be stored as a text file (extension TXT).

WE CLAIM:

1. Method for teaching a knowledge-based database for automatic defect classification, characterized by the following steps:
 - 5 - Selection of a review data file
 - Input of parameters and data by the user on one page (50) of the learning mode whereby the parameters and the data are known to the user,
 - Starting an alignment procedure and a procedure for adjusting the light intensity;
 - 10 - Automatic adjustment of the optimal intensity of the lighting by approaching a few defects and if necessary regulating to the optimal illumination;
 - Checking the detection using a few examples, whereby the optimization of the detection parameters is carried out using pictures,
 - Automatic approach of all defects of the wafer or the wafers , whereby the respective defect is detected and a descriptor is assigned to the respective defect,
 - 15 and
 - Analysis and automatic grouping of the descriptors of the defect.
2. Method according to Claim 1, characterized in that the input of parameters and data, the selection of the elements present on the semiconductor substrate,
20 whereby the elements can be memory circuits, logic circuits, a bare wafer, without resist or with resist.
3. Method according to Claim 2, characterized in that the parameters or data of the layers on the wafer comprise the data of a polymer layer, an oxide layer, a contact
25 or a metal layer.
4. Method according to Claim 1, characterized in that the user selects the lighting type, at least one lens used and a focus type.

5. Method according to Claim 4, characterized in that for the lighting type, bright field, UV or DUV is selected.
- 5 6. Method according to Claim 4, characterized in that the default setting is bright field and the lens has a 100X magnification.
7. Method according to Claim 4, characterized in that a manual two-point alignment is carried out, whereby a first point is aligned manually by approaching a table, that during the teaching of the first point data are automatically stored for the auto alignment file, and that each alignment point is taught with three different magnifications of the lens.
10
8. Method according to Claim 1, characterized in that the adjusting of the optimal intensity of lighting is achieved by random selection of a specific number of defects, approaching the selected defects, taking a picture of each defect with a start value for the brightness of the illumination and adjustment of the illumination using a histogram evaluation.
15
9. Method according to Claim 8, characterized in that for the adjusting of the optimal intensity of the lighting, only defects are used that are no larger than 25% of the video picture width and height.
20
10. Method according to Claim 8, characterized in that 20 defects are used to adjust the intensity of the lighting.
25
11. Method according to Claim 1, characterized in that of the automatically approached defects on the wafer, pictures are taken and temporarily stored until pictures are taken of all the defects.

12. Method according to Claim 11, characterized in that after all the pictures are taken, these are shown on the display (11) as thumbnails.

13. Method according to Claim 12, characterized in that a few thumbnails are rejected if the thumbnails exceed a threshold for the focus.

14. Method according to Claim 1, characterized in that the analysis and automatic grouping of the descriptors of the defects divides the thumbnails of the defects recorded into groups and that on the display the first nine examples of a selected group of defects are displayed in a thumbnail representation.

Abstract

The invention relates to a method of learning a knowledge-based database used in automatic defect classification. According to this method, the user is spared a series of entries as the system carries out an automatic learn mode, which requires a reduced number of user entries.